Toward Everyday Perceptual and Physiological Augmentation

Yujie Tao
yjtao@stanford.edu
Stanford University
Stanford, California, USA

Tan Gemicioglu
tg399@cornell.edu
Cornell Tech
New York, New York, USA

Sam Chin
chins@mit.edu
MIT Media Lab
Cambridge, Massachusetts, USA

Bingjian Huang
bingjian20@dgp.toronto.edu
University of Toronto
Toronto, Ontario, Canada

Jas Brooks
jasb@mit.edu
MIT CSAIL
Cambridge, Massachusetts, USA

Sean Follmer
sfollmer@stanford.edu
Stanford University
Stanford, California, USA

Pedro Lopes
pedrolopes@uchicago.edu
University of Chicago
Chicago, Illinois, USA

Suranga Nanayakkara
suranga@ahlab.org
National University of Singapore
Singapore, Singapore

Figure 1: Showcasing the wide variety of perceptual and physiological augmentation devices. (a) audio augmentation to support social interactions [22] (b) vibrotactile jacket for situational awareness in drone teleoperation [11] (c) multisensory device to augment musical interval recognition [5] (d) augmented breathing during information work [8].

ABSTRACT

Human senses are fundamental to how we interpret and interact with the world. Computing devices are increasingly coupled with the human sensory system through interfaces such as smart glasses, earbuds, and wristbands. This opens up opportunities to dynamically mediate, modify, and augment perceptual experiences and physiological processes through multisensory stimulation. These devices go beyond assistive technologies designed for individuals with sensory impairments (e.g., hearing aids) and are now available for everyday use. Applications range from enriching immersive entertainment experiences to supporting well-being through multisensory interventions.

The UIST community has been a key venue for introducing many proof-of-concept prototypes in multisensory stimulation. However, gaps remain in systematically understanding how such technologies can be designed, studied, and contextualized in long-term, everyday use. This workshop will examine barriers to transitioning prototypes from proof-of-concepts into systems for real-world use. The session will feature keynote talks, demo sessions, and an interactive device-swap activity where participants exchange and wear different devices during the afternoon session, and conclude with an open discussion to develop implementation frameworks.

CCS CONCEPTS

• **Human-centered computing** → **Interaction paradigms**; **Ubiquitous and mobile devices**.

KEYWORDS

perceptual augmentation, physiological augmentation, sensory augmentation, ubiquitous devices, wearables, multisensory interfaces

ACM Reference Format:
Yujie Tao, Tan Gemicioglu, Sam Chin, Bingjian Huang, Jas Brooks, Sean Follmer, Pedro Lopes, and Suranga Nanayakkara. 2025. Toward Everyday Perceptual and Physiological Augmentation. In *The 38th Annual ACM Symposium on User Interface Software and Technology (UIST Adjunct '25), September 28-October 1, 2025, Busan, Republic of Korea.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3746058.3758471

UIST Adjunct '25, September 28-October 1, 2025, Busan, Republic of Korea

ACM ISBN 979-8-4007-2036-9/2025/09
https://doi.org/10.1145/3746058.3758471

1 INTRODUCTION

Human senses are inherently rich, yet constrained by biological limitations. Throughout history, people have developed tools to extend these capabilities—telescopes make distant celestial bodies visible, while microscopes uncover microscopic structures beyond natural perception. Rooted in psychological and medical research,

early efforts in perceptual augmentation focused primarily on supporting individuals with sensory impairments, leading to a deeper understanding of sensory mechanisms like neuroplasticity [1] and innovations such as bionic eyes [15] and hearing aids [25].

Emerging computing devices—such as smart glasses [16], wristbands, and earbuds [17]—can be increasingly coupled with our sensory and physiological systems. Equipped with advanced sensors and actuators, these devices can deliver multisensory stimuli that influence human perception and modify physiological activity. The range of stimuli includes not only visual and auditory signals but also touch [10, 14], smell [3], taste [2], and even interoception—the awareness of internal bodily states [4, 9]. Through such stimuli, these devices can augment our perception of ourselves, other people, and the world around us. Meanwhile, other devices use the same stimuli to augment physiological processes such as muscle control [13, 26], breathing [6, 9], and heartbeat [7, 23]. Although computing devices show emerging capabilities of everyday perceptual and physiological augmentation, a comprehensive understanding to guide their development and evaluation has yet to be established.

Research from the UIST community and the broader field of Human-Computer Interaction (HCI) has been a driver of technical innovation in multisensory stimulation, enabling new ways to stimulate human senses. For instance, prior work has developed novel techniques for rendering fine-grained tactile feedback through mechanical actuators [10], and sensory illusions [21]. Moreover, we also see explorations of perceptual and physiological augmentation contextualized in application domains such as social interactions [20, 22], learning [5, 8], well-being [9, 24], and human-robot-interaction [11]. For these advancements to go beyond the research community and reach their full potential, they must be designed for long-term, everyday use.

This workshop aims to bring together researchers excited about perceptual and physiological augmentation in everyday use. We will trace the history of sensory technologies and build an interdisciplinary understanding of where HCI research stands in this space. Through interactive demos, attendees will share technical advancements, discussing potential taxonomies and generalizable approaches for designing multisensory stimulation. Lastly, we will engage in open discussions on the applications and how to contextualize device design within real-world scenarios.

This workshop builds upon prior efforts, such as Workshop on Sensorimotor Devices (CHI'25) [19], Workshop on Amplification and Augmentation of Human Perception (CHI'17) [18], Workshop on Assistive Augmentation (CHI '14) [12], Shonan Meeting on Augmented Perception (2024) and Smell, Taste, and Temperature Interfaces (CHI'23) [3].

2 SCOPE

During the workshop, we will explore the following topics:

Augmentation Techniques. What are previous attempts to modify or enhance human senses? How can current methods for stimulating different senses be categorized? Are there generalizable principles or frameworks for designing effective multisensory stimulation? What theories or insights can we draw from related fields such as psychology, neuroscience, and medicine?

Evaluation of Perceptual and Physiological Augmentation. What evaluation metrics are currently used to assess perceptual & physiological augmentation? What measures should researchers consider when designing these systems for everyday contexts?

Designing for Practical Applications. What are meaningful real-world applications of perceptual & physiological augmentation? What are bottlenecks to designing systems for everyday use?

Safety and Ethical Considerations What ethical considerations arise when we alter or extend human perception?

3 WORKSHOP PLAN

Our workshop is a full-day, in-person event designed to engage 25-35 participants in interactive and reflective activities around the workshop's themes. It is structured to emphasize community-building, hands-on experimentation, and interdisciplinary exchange.

A dedicated workshop website will provide detailed information about the theme, goals, submission process, schedule, and organizers. After the event, it will host post-workshop materials such as documentation and follow-up opportunities.

3.1 Preparatory Activities

As part of the workshop application, we invite applicants to briefly share their research experience and motivation for joining the workshop. Applicants may also indicate whether they would like to bring a demo: an option we will actively encourage.

One week before the workshop, we will: (1) Create a shared folder where attendees will be asked to upload a one-slide self-introduction and share links, images, or notes about their ongoing projects. (2) Circulate a participant slide deck to facilitate informal introductions before the workshop's opening session.

3.2 Workshop Activities

3.2.1 Opening and Speed Introductions (45 minutes). The day begins with a welcome from the organizers and an overview of the workshop structure and goals. This is followed by a speed-introduction session where each participant introduces themselves using their pre-submitted slide. This activity highlights participants' interests and backgrounds to fostering engagement.

3.2.2 Keynote Talks (60-120 minutes). Guest speakers (experts in HCI and adjacent fields such as neuroscience and psychology) will deliver a keynote, followed by Q&A. The keynotes will set the tone for the day, offering a high-level perspective on existing research on this topic to encourage interdisciplinary discussion.

3.2.3 Interactive Demo Sessions (120 minutes). We will host three 40-minute demo sessions, rotating participants so everyone has the opportunity to explore a variety of interactive projects. These sessions will feature participant-led demos ranging from functional prototypes to early experiment designs. The emphasis is on exchange, feedback, and multi-sensory engagement.

3.2.4 Sense & Share Activity (Ongoing + Afternoon Debrief). This activity invites participants to bring a low-fidelity or passive version of their perceptual or physiological augmentation project to be swapped with another attendee in a "Secret Santa"-style exchange. The recipient will wear or use the device throughout the day during workshop activities. In the late afternoon, we will reconvene for a

reflective debrief: original creators and users will pair up and share feedback about usability, comfort, breakdowns, and unexpected effects. This activity invites a playful yet critical approach to real-world deployment for everyday use.

3.2.5 Group Discussions and Thematic Reflection. In the afternoon, participants will break into small, facilitated discussion groups centered on the following two themes: (1) **"Where Are We From?"** This section explores participants' disciplinary and methodological starting points, from HCI and design to neuroscience, bioengineering, and beyond. What are the assumptions baked into each field's approach to augmentation? What can we learn from adjacent practices? How do we unify methods? (2) **"Everyday Use and Failure"** This section focuses on the practical and ethical challenges of deploying perceptual and physiological augmentation in real-world settings. Participants will reflect on what makes a device "usable," where it fails, and how people interpret (or misinterpret) the sensory experiences. Each group will use sticky notes or shared documents to capture their conversation, which will then be synthesized in a brief large-group sharing session.

3.3 Post-Workshop Activities

Following the event, we will: (1) Publish a summary of workshop insights, photos, and key discussion points on the website. (2) Share demo documentation, slides, and other contributed materials with participants. (3) Invite all attendees to join an ongoing mailing list or Discord server to continue exchanging resources, updates, and collaboration opportunities. (4) Prepare a workshop report or position piece summarizing outcomes and future directions, to be submitted to venues such as *ACM Interactions* or *ACM CHI*.

REFERENCES

[1] Paul Bach-Y-Rita, Carter C. Collins, Frank A. Saunders, Benjamin White, and Lawrence Scadden. 1969. Vision Substitution by Tactile Image Projection. *Nature* 221, 5184 (March 1969), 963–964. https://doi.org/10.1038/221963a0 557 citations (Crossref) [2024-11-14].

[2] Jas Brooks, Noor Amin, and Pedro Lopes. 2023. Taste Retargeting via Chemical Taste Modulators. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology* (San Francisco, CA, USA) *(UIST '23)*. Association for Computing Machinery, New York, NY, USA, Article 106, 15 pages. https://doi.org/10.1145/3586183.3606818

[3] Jas Brooks, Pedro Lopes, Judith Amores, Emanuela Maggioni, Haruka Matsukura, Marianna Obrist, Roshan Lalintha Peiris, and Nimesha Ranasinghe. 2021. Smell, taste, and temperature interfaces. In *Extended abstracts of the 2021 CHI conference on human factors in computing systems*. 1–6.

[4] Jas Brooks, Alex Mazursky, Janice Hixon, and Pedro Lopes. 2024. Augmented Breathing via Thermal Feedback in the Nose. In *Proceedings of the 37th Annual ACM Symposium on User Interface Software and Technology* (Pittsburgh, PA, USA) *(UIST '24)*. Association for Computing Machinery, New York, NY, USA, Article 26, 11 pages. https://doi.org/10.1145/3654777.3676438

[5] Sam Chin, Cathy Mengying Fang, Nikhil Singh, Ibrahim Ibrahim, Joe Paradiso, and Pattie Maes. 2024. Purrfect Pitch: Exploring Musical Interval Learning through Multisensory Interfaces. https://doi.org/10.48550/arXiv.2407.09721 arXiv:2407.09721 [cs].

[6] Kyung Yun Choi, Neska ElHaouij, Jinmo Lee, Rosalind W. Picard, and Hiroshi Ishii. 2022. Design and Evaluation of a Clippable and Personalizable Pneumatic-haptic Feedback Device for Breathing Guidance. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 6, 1 (March 2022), 6:1–6:36. https://doi.org/10.1145/3517234

[7] Jean Costa, Alexander T. Adams, Malte F. Jung, François Guimbretière, and Tanzeem Choudhury. 2016. EmotionCheck: Leveraging Bodily Signals and False Feedback to Regulate Our Emotions. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '16)*. Association for Computing Machinery, New York, NY, USA, 758–769. https://doi.org/10.1145/2971648.2971752

[8] Tan Gemicioglu, Elijah Hopper, Brahmi Dwivedi, Richa Kulkarni, Asha Bhandarkar, Priyanka Rajan, Nathan Eng, Adithya Ramanujam, Charles Ramey, Scott M. Gilliland, Celeste Mason, Caitlyn Seim, and Thad Starner. 2024. Passive Haptic Rehearsal for Augmented Piano Learning in the Wild. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 8, 4 (Nov. 2024), 187:1–187:26. https://doi.org/10.1145/3699748

[9] Tan Gemicioglu, Thalia Viranda, Yiran Zhao, Olzhas Yessenbayev, Jatin Arora, Jane Wang, Pedro Lopes, Alexander T. Adams, and Tanzeem Choudhury. 2024. BreathePulse: Peripheral Guided Breathing via Implicit Airflow Cues for Information Work. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 8, 4 (Nov. 2024), 188:1–188:33. https://doi.org/10.1145/3702211

[10] Bingjian Huang, Siyi Ren, Yuewen Luo, Qilong Cheng, Hanfeng Cai, Yeqi Sang, Mauricio Sousa, Paul H Dietz, and Daniel Wigdor. 2025. VibraForge: A Scalable Prototyping Toolkit For Creating Spatialized Vibrotactile Feedback Systems. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems (CHI '25)*. Association for Computing Machinery, New York, NY, USA, Article 1137, 18 pages. https://doi.org/10.1145/3706598.3714273

[11] Bingjian Huang, Zhecheng Wang, Qilong Cheng, Siyi Ren, Hanfeng Cai, Antonio Alvarez Valdivia, Karthik Mahadevan, and Daniel Wigdor. 2025. AeroHaptix: A Wearable Vibrotactile Feedback System for Enhancing Collision Avoidance in UAV Teleoperation. *IEEE Robotics and Automation Letters* 10, 5 (2025), 4260–4267. https://doi.org/10.1109/LRA.2025.3548866

[12] Jochen Huber, Jun Rekimoto, Masahiko Inami, Roy Shilkrot, Pattie Maes, Wong Meng Ee, Graham Pullin, and Suranga Chandima Nanayakkara. 2014. Workshop on assistive augmentation. In *CHI'14 Extended Abstracts on Human Factors in Computing Systems*. 103–106.

[13] Shunichi Kasahara, Kazuma Takada, Jun Nishida, Kazuhisa Shibata, Shinsuke Shimojo, and Pedro Lopes. 2021. Preserving Agency During Electrical Muscle Stimulation Training Speeds up Reaction Time Directly After Removing EMS. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21)*. Association for Computing Machinery, New York, NY, USA, 1–9. https://doi.org/10.1145/3411764.3445147

[14] Pedro Lopes, Sijing You, Lung-Pan Cheng, Sebastian Marwecki, and Patrick Baudisch. 2017. Providing Haptics to Walls & Heavy Objects in Virtual Reality by Means of Electrical Muscle Stimulation. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 1471–1482. https://doi.org/10.1145/3025453.3025600

[15] Kamil Nowik, Ewa Langwińska-Wośko, Piotr Skopiński, Katarzyna E. Nowik, and Jacek P. Szaflik. 2020. Bionic eye review – An update. *Journal of Clinical Neuroscience* 78 (Aug. 2020), 8–19. https://doi.org/10.1016/j.jocn.2020.05.041

[16] David Ramsay and Joe Paradiso. 2022. Peripheral Light Cues as a Naturalistic Measure of Focus. In *ACM International Conference on Interactive Media Experiences*. ACM, Aveiro JB Portugal, 375–380. https://doi.org/10.1145/3505284.3532984

[17] Tobias Röddiger, Michael Küttner, Philipp Lepold, Tobias King, Dennis Moschina, Oliver Bagge, Joseph A. Paradiso, Christopher Clarke, and Michael Beigl. 2025. OpenEarable 2.0: Open-Source Earphone Platform for Physiological Ear Sensing. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 9, 1 (March 2025), 1–33. https://doi.org/10.1145/3712069 Publisher: Association for Computing Machinery (ACM).

[18] Albrecht Schmidt, Stefan Schneegass, Kai Kunze, Jun Rekimoto, and Woontack Woo. 2017. Workshop on amplification and augmentation of human perception. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. 668–673.

[19] Paul Strohmeier, Laia Turmo Vidal, Gabriela Vega, Courtney N. Reed, Alex Mazursky, Easa AliAbbasi, Ana Tajadura-Jiménez, and Jürgen Steimle. 2025. Sensorimotor Devices: Coupling Sensing and Actuation to Augment Bodily Experience. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25)*. Association for Computing Machinery, New York, NY, USA, Article 799, 7 pages. https://doi.org/10.1145/3706599.3706735

[20] Yujie Tao, Jordan Egelman, and Jeremy N Bailenson. 2024. I Feel You: Impact of Shared Body Sensations on Social Interactions in Virtual Reality. In *2024 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. IEEE, 1097–1106.

[21] Yujie Tao, Shan-Yuan Teng, and Pedro Lopes. 2021. Altering perceived softness of real rigid objects by restricting fingerpad deformation. In *The 34th Annual ACM Symposium on User Interface Software and Technology*. 985–996.

[22] Yujie Tao, Libby Ye, Jeremy N Bailenson, and Sean Follmer. in press. Audio Personas: Augmenting Social Perception via Body-Anchored Audio Cues. *ACM Transactions on Computer-Human Interaction* (in press). https://arxiv.org/abs/2505.00956

[23] Andreia Valente, Dajin Lee, Seungmoon Choi, Mark Billinghurst, and Augusto Esteves. 2024. Modulating Heart Activity and Task Performance Using Haptic Heartbeat Feedback: A Study Across Four Body Placements. In *Proceedings of the 37th Annual ACM Symposium on User Interface Software and Technology (UIST '24)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3654777.3676435

[24] Yiran Zhao, Yujie Tao, Grace Le, Rui Maki, Alexander Adams, Pedro Lopes, and Tanzeem Choudhury. 2023. Affective Touch as Immediate and Passive Wearable Intervention. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 6, 4 (Jan.

2023), 200:1–200:23. https://doi.org/10.1145/3569484

[25] Yunfang Zheng, Jacob Swanson, Janet Koehnke, and Jianwei Guan. 2022. Sound Localization of Listeners With Normal Hearing, Impaired Hearing, Hearing Aids, Bone-Anchored Hearing Instruments, and Cochlear Implants: A Review. *American Journal of Audiology* 31, 3 (Sept. 2022), 819–834. https://doi.org/10.1044/2022_AJA-22-00006

[26] Hongyu Zhou, Tom Kip, Yihao Dong, Andrea Bianchi, Zhanna Sarsenbayeva, and Anusha Withana. 2025. Juggling Extra Limbs: Identifying Control Strategies for Supernumerary Multi-Arms in Virtual Reality. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems (CHI '25)*. Association for Computing Machinery, New York, NY, USA, 1–16. https://doi.org/10.1145/3706598.3713647